DOCUMENT RESUME

ED 259 884 SE 045 848

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TITLE Electrical and Chemical Experiments...from Edison.
INSTITUTION Thomas Alva Edison Foundation, Southfield, MI.
PUB DATE 80
NOTE 36p.
AVAILABLE FROM Thomas Alva Edison Foundation, 21000 West 10 Mile Rd., Southfield, MI 48075 ($.75 each; 3 for $2.00).
PUB TYPE Guides - Classroom Use - Materials (For Learner) (051)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS *Chemistry; *Electricity; *Elementary School Science; Intermediate Grades; Science Activities; Science Education; *Science Experiments; Secondary Education; *Secondary School Science
IDENTIFIERS *Electrochemistry

ABSTRACT

Background information, lists of materials needed, and procedures are provided for 12 electrochemistry experiments. The experiments involve investigating: (1) a simple electrical circuit; (2) how a doorbell works; (3) how a two-way switch works; (4) conductors and insulators; (5) controlling current with a pencil; (6) what an electrolyte is; (7) electricity from a lemon; (8) the first electric battery; (9) gases from electrified salt water; (10) ink for secret messages; (11) carbon dioxide (the fire killer); and (12) candy crystals from a sugar solution. Diagrams illustrating procedures and/or equipment are included when applicable. (JN)

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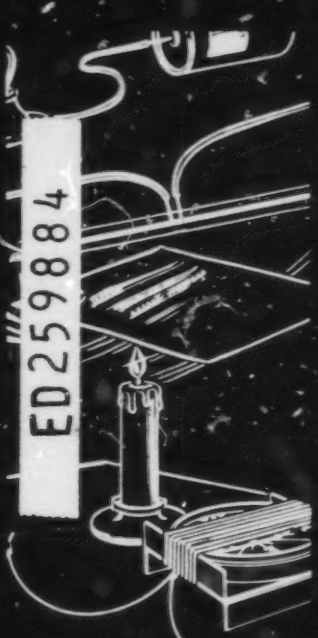

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Arthur J. Palmer

ELECTRICAL AND CHEMICAL EXPERIMENTS...FROM EDISON

Text by:
ROBERT F. SCHULTZ

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1980, Third Printing

Publication of the

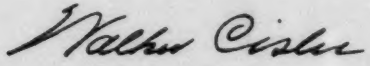
THOMAS ALVA EDISON FOUNDATION
Cambridge Office Plaza, Suite 143
18280 West Ten Mile Road
Southfield, Michigan 48075

TO THE YOUNG PEOPLE OF AMERICA

Because of his many achievements in the field of electricity, people called Thomas Edison the electrical wizard. Yet, oddly enough, Edison thought of himself as a chemist.

Perhaps the reason Edison felt at home experimenting in both fields is that electricity and chemistry have much in common. Indeed, the principles they share make up a separate scientific field called electrochemistry. Among other things, this booklet attempts to acquaint you with that field.

But more important, it hopes to ignite within you the spark of scientific adventure . . . the challenge to find things out for yourself by experimenting. Possibly, in doing some of the experiments on the following pages, you will experience a taste of the excitement and satisfaction most scientists and engineers get from their work. Who knows, you may even start thinking about this kind of work as a career.



Walker L. Cisler
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EXPERIMENTS

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CHEMISTRY AND ELECTRICITY

Did you know that chemistry and electricity are strongly related to one another?

In what way are they related? you might ask. Well, for one thing, electricity can cause certain chemical changes to occur. For example it can force water to break up into hydrogen and oxygen. At the same time, certain chemical changes can produce electricity. These are the changes that make electric batteries work.

Also, a chemical change involves electrons, and so does electricity. Electricity is, in fact, the flow of electrons. We call this flow current.

Some of the experiments in this booklet will demonstrate the points we've just made . . . that is, the relationship between chemistry and electricity. Other experiments will be purely electrical or purely chemical. Let's start with simple electricity.

You've no doubt heard the words electrical circuit. An electrical circuit is nothing more than a path for electrons to follow. It usually refers to an unbroken path, which we call a closed circuit. Circuits must be closed before current can flow. But if the circuit is interrupted, like when a switch is turned off, then it is an open circuit. Current cannot flow in an open circuit. This brings us to the first experiment.

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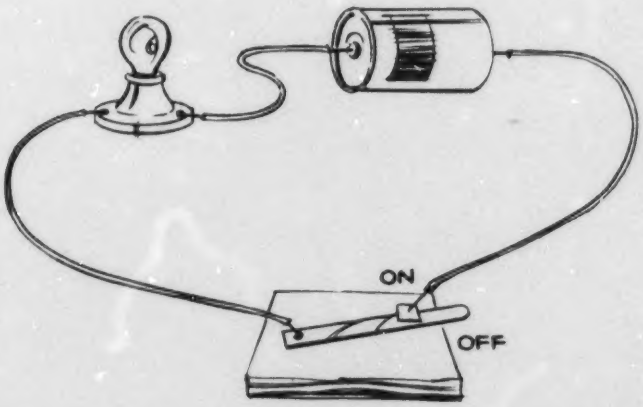
EXPERIMENT 1: A Simple Electrical Circuit

THINGS NEEDED: *Penlight bulb. Small socket. Flashlight battery or large 1½-volt dry cell. Few feet of insulated wire, any kind. Switch (we'll build this item).*

We may as well begin by making the switch. While we're at it, let's make two. We'll need the second switch for another experiment anyway.

Get a discarded tin can and wash it out. Completely remove both the top and bottom. Then cut the can lengthwise and flatten it out. Be very careful of those sharp edges. From this sheet of metal cut two strips ½" by 3" and two pieces ½" by ½". Don't throw away the leftover metal yet.

Next cut two blocks of wood about 2" by 3".



With screws, assemble each switch as shown in the drawing. Make sure the contacting sections of the metal have been scraped clean. Also leave enough room at the action end of the switch for another contact to be added. That will have to be done for a later experiment. Set one switch aside for the time being.

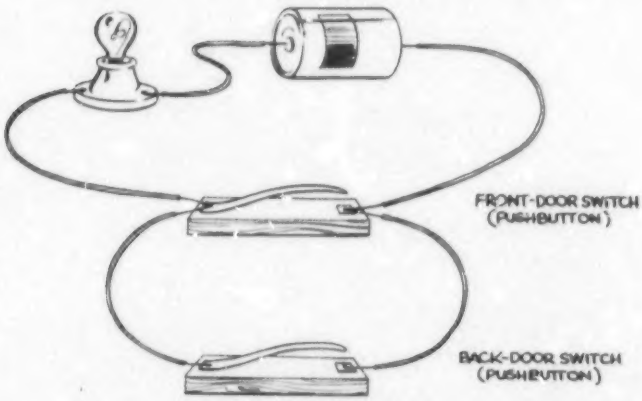
Now connect the circuit as shown. Use tape to hold the wires on the battery (soldering the wires in place would be better if you are able to do so). Note that when the switch is ON, the circuit is closed and the bulb lights up. When the switch is OFF, the circuit is open and current cannot flow.

EXPERIMENT 2: How a Doorbell Circuit Works

THINGS NEEDED: *Same as in previous experiment, plus the second switch.*

To set up the doorbell circuit, we'll have to convert both switches to pushbuttons. That's easy to do. Simply bend each arm slightly upward and position it over the contact. The light, of course, will serve as the bell.

With the circuit connected as shown, try each "pushbutton" separately. Can you trace the completed circuit in each case? Note that when you "ring the back doorbell," it's as if the front-door switch wasn't even there. And vice versa.

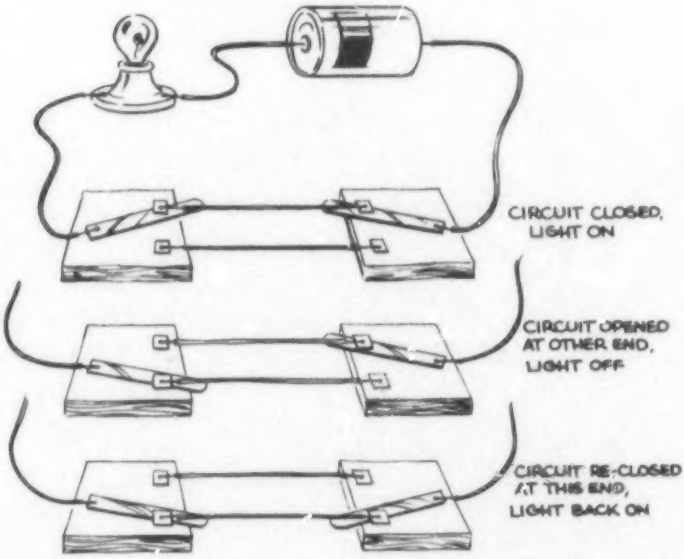


These pushbutton switches are connected in parallel with one another. In a parallel circuit, there could be a dozen or more switches. And each one would work separately, yet not be affected by the other switches. Simple burglar systems work this way. An open switch is positioned at each window and door. The switches are connected in parallel with an alarm. A slight movement of any of the windows or doors will close the switch at that spot and RRRRINGGG THE ALARM.

EXPERIMENT 3: How a Two-Way Switch Works

THINGS NEEDED: *Same as in experiment no. 2, plus two more tin-can pieces ½" by ½". (Now you can throw the remaining tin-can scraps away).*

Ever been in a two-story house where the stair light can be turned on or off at either the top or bottom of the stairs? Some houses have a similar two-switch arrangement for the kitchen light when the kitchen has two doorways. No matter which way you enter or leave the room, you can control the light.



This experiment shows how such a circuit works. But first we must change our single throw switches to double throw. Do this by adding another contact as shown. Now each switch will make contact whether the arm is up or down.

Hook the circuit up according to the diagram and run a few tests. Note that when both switch arms are up, the circuit is closed and the bulb glows. The same is true when both arms are down.

But when either arm is up and the other is down, the circuit will be open. And the bulb will stay dark until one of the switch arms is moved. This explains why you can control the light from either switch no matter how the other switch is set.

EXPERIMENT 4: Conductors and Insulators

THINGS NEEDED: *Same as in experiment no. 1, except for the switch. Various test materials from around the house.*

As we have found in the experiments so far, current will flow in a circuit as long as the circuit is closed. However, the materials in the circuit must be the right kind. In other words, they must be able to conduct electricity.

All materials conduct electricity to some extent. The ones that pass electricity with ease are called conductors. Silver, copper, and aluminum are all good conductors. Those that pass electricity with difficulty are called insulators. Rubber, glass, and porcelain are good insulators. Most materials, however, are neither good conductors nor good insulators but lie somewhere between.

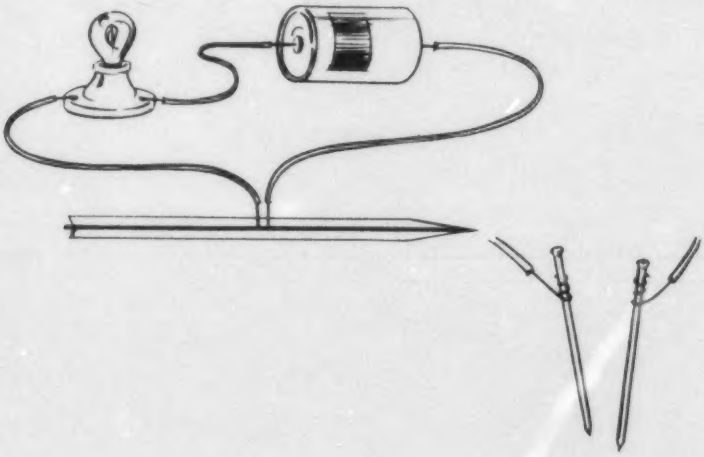
The circuit shown will enable you to test some common items. Try to collect as many different kinds of materials as you can. Make sure when you touch the material you get good contact. If the bulb lights up, you know the material is a conductor. If the bulb doesn't light up, the material is not a conductor.

EXPERIMENT 5: Controlling Current With a Pencil

THINGS NEEDED: *Same as in experiment no. 1, except for the switch. Old pencil.*

The "lead" in an ordinary pencil consists mostly of graphite, fine clay, and wax. This mixture contains no lead. But because people began calling it lead years ago, we still call it lead today.

A soft-lead pencil has more graphite than a hard one. Now although graphite itself can conduct electricity well, the mixture in a pencil conducts rather poorly. We're going to use pencil lead to show that the length of a conductor affects the amount of current that flows in a circuit.



Carefully slit the pencil so that the lead is exposed. Now place both wires of the testing circuit near one end of the lead. The bulb should light up, although not nearly as brightly as with the wires touching one another.

If nothing at all happens when you touch the lead, you'll have to press harder. One way to get extra pressure on the lead is as follows: Wrap each wire end tightly around the top of a long nail. Then use the nails as probes. In this way you'll be able to press quite hard. While pressing hard, slide one nail away from the other and

notice what the bulb does. The farther apart the nails become, the dimmer the bulb gets.

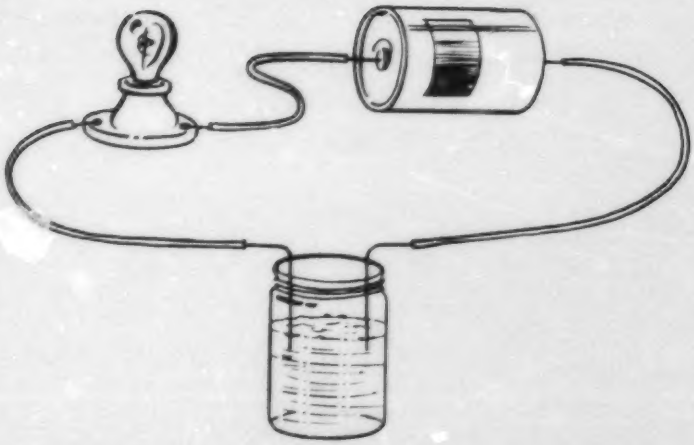
What this experiment illustrates is that all conductors contain a certain amount of electrical resistance. And as the conductor gets longer, this resistance can build up to a noticeable level. Even good conductors like copper can't carry electricity too far without weakening the current.

This experiment also shows how a rheostat (REE-oh-stat) works. A rheostat regulates current flow. For example, the volume control on a radio is a rheostat. Room lights are often dimmed by a rheostat, somewhat like you dimmed the flashlight bulb . . . by running the contact arm over a longer length of conductor. This increases resistance, which reduces current flow.

EXPERIMENT 6: What Is an Electrolyte?

THINGS NEEDED: *Same as in experiment no. 1, except for the switch. Various household liquids in separate containers.*

That's a high-sounding word electrolyte (eh-LEK-troe-lite). But don't let it scare you. It simply refers to a substance that is able to conduct electricity when dissolved in water. Dry salt, as you may have learned in experiment no.



4, cannot conduct electricity. But a solution of salt water conducts it quite well. You might say, then, that an electrolyte is a liquid conductor.

For the test liquids, try separate water solutions of sugar, baking soda, and starch. Also try water by itself. Then see what happens as you begin adding salt to the water. You might want to investigate the following liquids too: lemon juice, salad oil, vinegar, and milk.

Why do some solutions conduct electricity while others do not? It has to do with the chemical compounds dissolved in the solutions. If the chemicals easily break up in the water into particles called ions (EYE-uns), the solution will conduct. Otherwise, the solution will conduct poorly or not at all.

But such theory belongs in high school chemistry books. We mention it only because it is

another example of the relationship between electricity and chemistry. Let us now try a few experiments involving both sciences. This field is known as electrochemistry.

EXPERIMENT 7: Electricity From a Lemon

THINGS NEEDED: *A lemon. Small strip of copper about ½" by 3". Small strip of zinc, same size (you can get zinc from the sides of an old dry cell, or you can use galvanized sheet metal — it's zinc coated). A galvanometer (this is easy to make . . . see text).*

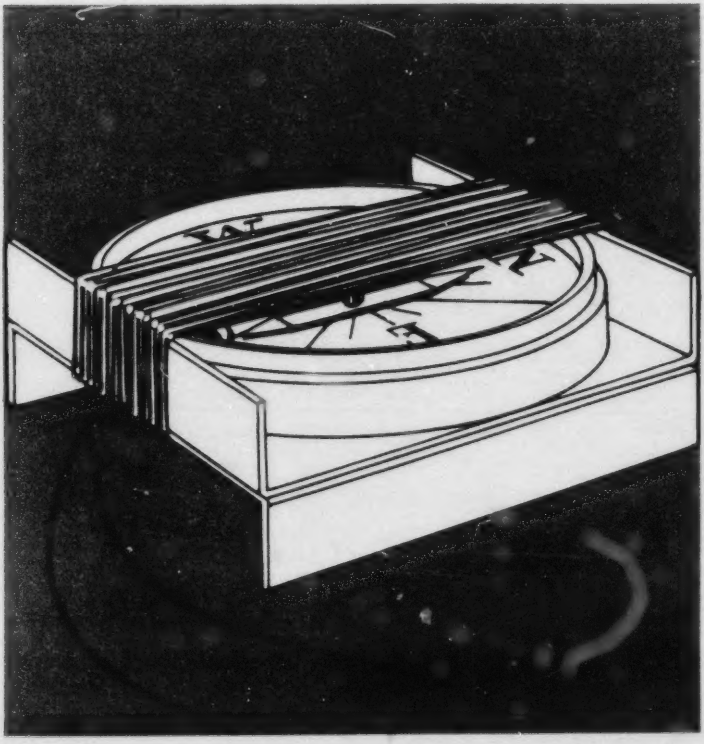
Here's an interesting demonstration in which a piece of fruit plays the role of an electrical cell. The act won't last long. And the amount of electricity produced is quite small. But it nevertheless is first-hand proof that chemistry can indeed cause current to flow in a closed circuit.

Since the current in this case is not nearly enough to light a bulb, we'll have to prove our results some other way. We'll use a galvanometer. This is a very sensitive instrument for detecting weak flows of electricity.

To make a galvanometer, we'll need a compass, a piece of stiff cardboard, and a small spool of magnet wire (#28 or finer).

Cut a piece of cardboard as wide as the compass but long enough to fold up at the ends (see sketch). Then cut and fold another piece the same as the first. Glue the two cardboard pieces back to back to form a cradle, as shown.

Place the compass inside the cradle so that the N-S axis points toward the closed sides. Finally, wind about 100 turns of wire around the compass and cradle right over the N-S axis. Twist the free ends a few times to keep the coil from unwinding.



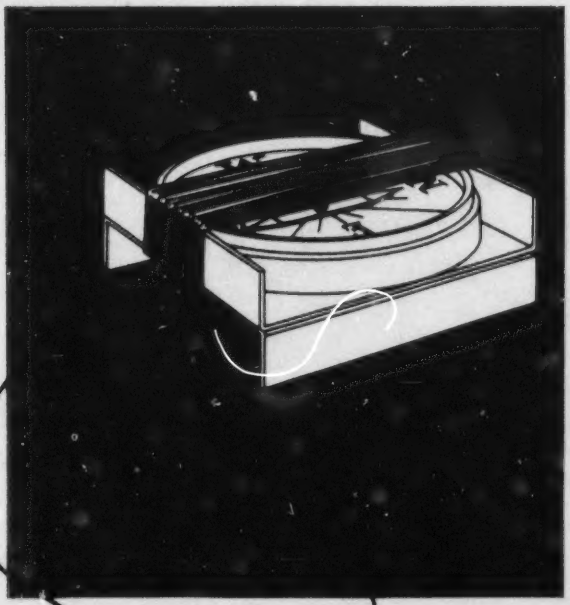
Trim both ends of the coil to about 12" in length. Then scrape ½" of enamel insulation off the wire tips. And that's it. That's our galvanometer.

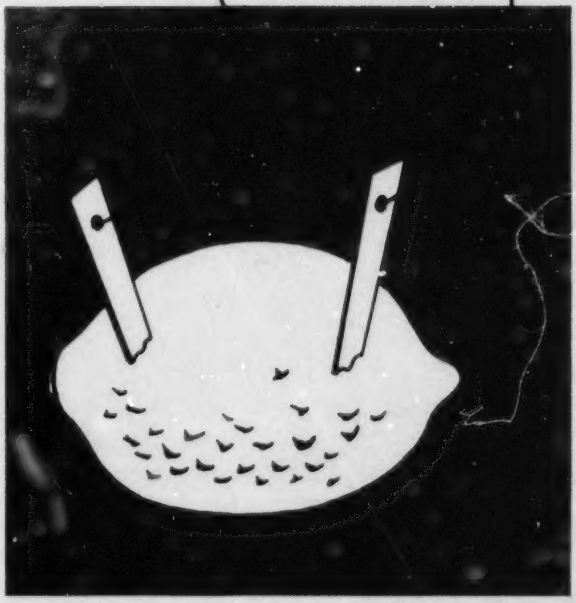
Here's how it works: Whenever current flows through the coils, it creates a magnetic field around the coils. With the coils aligned in the N-S direction, the field tends to swing the needle toward the E-S direction. A weak current will set up a weak field and swing the needle only slightly. A stronger current will swing the needle farther.

Now for the lemon. Roll it on a flat surface, pressing down with the palm of your hand. This will break up the inside of the lemon and let the juice flow freely. The lemon juice contains citric acid. And this acid is the electrolyte for our lemon battery.

Next cut two slits about ½" apart and insert the copper and zinc strips, or electrodes as they're called. Make sure the electrodes don't touch each other inside the lemon. Finally, connect the galvanometer to the electrodes. The galvanometer must be level so that the compass needle can move freely. That should do it. The needle should indicate the flow of current . . . the chemical production of electricity.

By the way, don't put the lemon in the garbage can yet. We will use it later in the booklet to make invisible ink.





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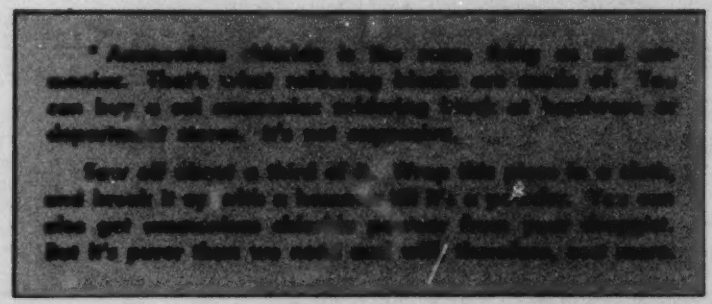
EXPERIMENT 8: The First Electric Battery

THINGS NEEDED: *Strip of copper about 1" by 6¼". Strip of zinc, same size. Two feet of wire. Few ounces of ammonium chloride.* Strip of thin felt ¼" by 6". Rubber band. Galvanometer from previous experiment.*

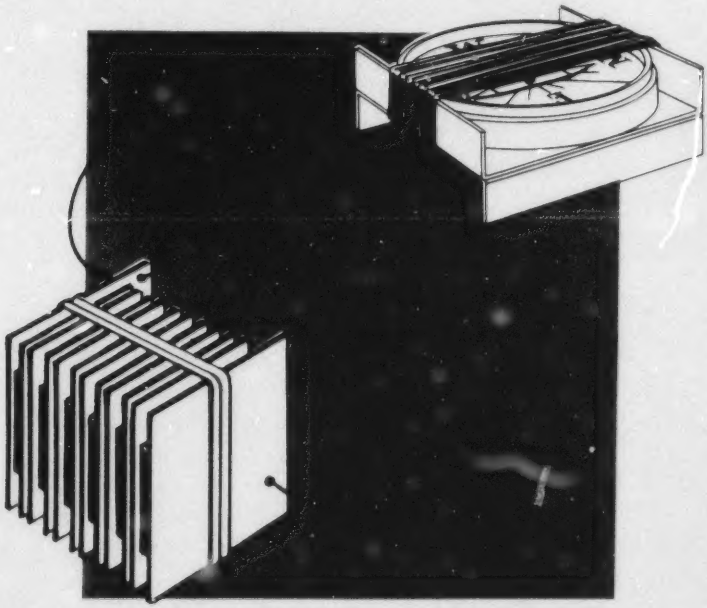
While we're on the subject of making electricity, let's build a battery. A battery is a group of two or more cells connected as one unit.

The battery we're going to make will be something like the one invented in 1800 by an Italian scientist named Alessandro Volta. His was the first electric battery . . . the first device for making electricity by chemical action. Today, simple chemical cells are called voltaic (vol-TAY-ik) cells in his honor. And when we use the word volt or talk of voltage, we also pay tribute to this man.



Start by cleaning both sides of each strip with steel wool or sandpaper. Then cut the copper strip into five squares 1" by 1". The piece left over, the sixth one, will be a little longer than the rest. Flatten the edges of all the pieces with a hammer. In the same way, cut the zinc strip and flatten the pieces. Also cut the felt into 6 pieces ¾" by ¾".

Dissolve the ammonium chloride into a few tablespoons of water. This will be our electrolyte solution. We'll need enough solution to wet all 6 pieces of felt. And as soon as the solution is ready, you may as well put the felt pieces into the solution. They must be thoroughly soaked to begin with. But before



they are used, you'll have to pinch each piece between the fingers to remove most of the electrolyte. Otherwise the completed battery will be wet all over. And that could short out some of the cells.

Before building the battery, punch a small hole in one end of the long copper piece and the long zinc piece. Attach a length of wire to the zinc strip by looping the wire through the hole and twisting it tightly (solder the connection if you can). Do the same with the copper strip.

Ready? First lay the long copper piece on a flat surface. On top of the copper, place one of the wet felt squares (don't forget to squeeze out the excess electrolyte). Next comes a zinc square. Then we just keep repeating the cycle: copper, felt, zinc, copper, felt, zinc, etc. When we're done, the long zinc piece should be on top. At this point, secure the pile with the rubber band. You've just built a battery. Let's see how well it works.

Connect the battery to the galvanometer. The battery should cause a more lively response than did the lemon cell. In fact, the battery might even be strong enough to produce a faint glow in the penlight bulb. This battery will make electricity by chemical action as long as the felt squares remain wet with ammonium chloride.

Here's another little experiment you can try if and when you take the battery apart. Keep the copper and zinc pieces from the ends of the pile. Leave the wires on.

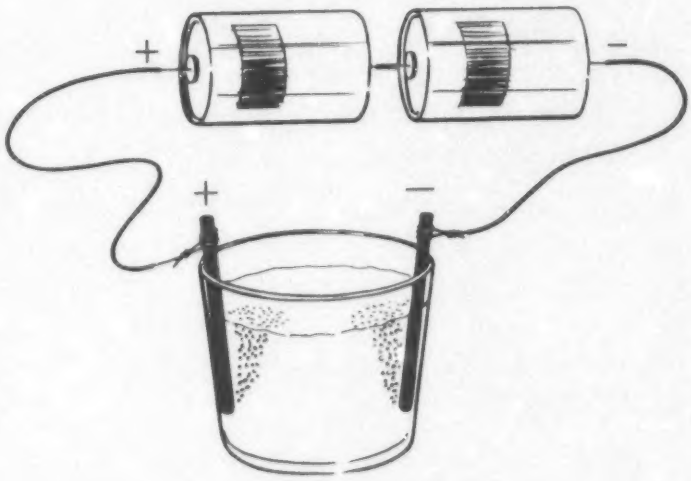
Clean the metal surfaces, and put some fresh electrolyte on a new piece of felt. Then place the felt between the metal pieces. Arrange the pieces so that the wires go in opposite directions. Otherwise the bare wire ends might touch and cause a short circuit.

After connecting the wires to the galvanometer, pinch the sandwich between your thumb and forefinger. You are holding a voltaic cell. Connect it to the galvanometer and see what it can do.

EXPERIMENT 9: Gases From Electrified Salt Water

THINGS NEEDED: *Salt. Two feet of wire. Glass container. Two dead flashlight batteries. Two fresh flashlight batteries.*

In the last two experiments, we proved to ourselves that chemicals can be used to make electricity. This time we're going to prove that



the reverse is also true . . . that electricity can be used to produce chemicals. The action is something like forcing a cell to run backwards.

Our cell in this experiment will have two carbon electrodes and a salt water electrolyte. The forcing is going to be done by the flashlight batteries.

For the carbon electrodes we'll use the rods from the two dead flashlight batteries. Remove the rods from these batteries with a saw or chisel. Scrape the rods clean and wash them in clear water. Then connect the rods to the batteries as shown. Make sure the wires are looped around the rods tightly and twisted to hold them in place.

The container must be nonmetallic. Either a glass or paper cup will do. Fill the container with water and stir in two tablespoons of salt.

When you immerse the carbon electrodes in the salt water electrolyte, do not allow the solution to touch the wire. If that happens, metal will chemically enter the solution and affect our results.

As soon as the electrodes touch the solution, current will start flowing between them. You will then notice many small bubbles streaming off both electrodes. On the electrode going to the negative (-) end of the battery, hydrogen forms. It is being unlocked from its union with oxygen in the compound H_2O, which of course

is water. On the electrode going to the positive (+) end of the battery, chlorine forms. It is being unlocked from its union with sodium in the compound known as sodium chloride, which is ordinary table salt. Electricity is causing this action to take place around both electrodes.

Electricity also produces other chemical changes in salt water. In industry, engineers use special equipment to take advantage of these changes. Along with hydrogen and chlorine, they are able to get sodium hydroxide from salt solutions. Sodium hydroxide, also called caustic soda, is used for making soap and lye. The process of taking a solution apart, which is what we did in this experiment, is known as electrolysis (eh-lek-TROL-i-sis).

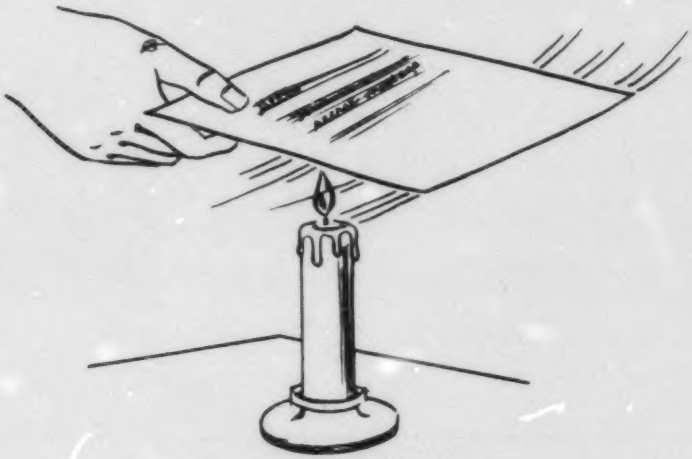
EXPERIMENT 10: Ink for Secret Messages

THINGS NEEDED: *Lemon juice. Toothpick or ink pen. Candle. Sheet of plain white paper.*

Now that we've learned something about electricity and how electricity relates to chemistry, let's have some fun doing a few chemical experiments.

Still have that lemon from experiment no. 7? We'd better use it before it gets rotten. Cut the lemon in half and squeeze out some of the juice into a saucer.

With the lemon juice as secret ink and a toothpick as a pen, write something on the sheet of white paper. It might be a good idea to break the toothpick in half first. In that way you'll have a blunter writing tip. It will also carry a little more ink. Make sure you use enough ink to leave a wet trail. But write lightly with the toothpick or you'll dig a readable impression in the paper.



Notice when the ink dries, it will be invisible. If what you had just written was a message to a friend, no one would be able to read what the message says except your friend. How would he do it? He knows how to make the writing visible.

The trick is to heat the paper until the materials in the dried ink begin to scorch. This is done

by passing the paper back and forth over a candle flame until the writing shows up. Care has to be taken not to hold the paper too long in one spot, because it will ignite.

Why does heating the ink make it visible? Chemical change. Just as heat chemically changes batter into cake, heat changes the ink to a new material. The ink, you see, burns at a lower temperature than the paper. And so its brown ashes (the new material) stand out nicely against the white paper background.

You can also write invisible letters with grapefruit juice, milk, or vinegar. Heat, again, makes the writing visible, for the same chemical reason.

EXPERIMENT 11: Carbon Dioxide — the Fire Killer

THINGS NEEDED: *Baking soda. Vinegar. Large bottle, such as a quart-size pop bottle. Candle.*

Carbon dioxide is a chemical compound containing one part carbon and two parts oxygen. Chemists write it as CO_2. It's one of our more common compounds. Human beings produce it, as a matter of fact, from the oxygen we breathe. Plants, in turn, absorb it to make oxygen. Soft-drink makers put it in pop to give it that gassy kick. And industry uses it to make dry ice, fire extinguishers, and other products.

We're going to do two things in this experiment on carbon dioxide gas. First, of course, we'll make it. Then we'll watch the gas smother fire . . . in this case, a candle flame.

Place the candle in a sink or dishpan. Be sure it is not near anything that could catch fire, like window curtains. Light the candle. Next put about a tablespoon of baking soda into the bottle. An easy way to do this is to put the powder on a small piece of paper and then use the paper as a chute.

Now pour a few ounces of vinegar into the bottle. Immediately the vinegar will start to foam. Place your thumb lightly over the bottle opening. You'll feel a pressure buildup. Why?

Baking soda is sodium bicarbonate. Vinegar contains acetic acid. When the two mix, a chemical reaction occurs releasing carbon dioxide gas. As the gas continues to form inside the bottle, the pressure on your thumb increases.

Before the foaming stops, remove your

thumb from the bottle. Tilt the bottle to a horizontal position and place the opening slightly above the candle flame, being careful not to spill the liquid. (But don't worry if you do. It's harmless.)

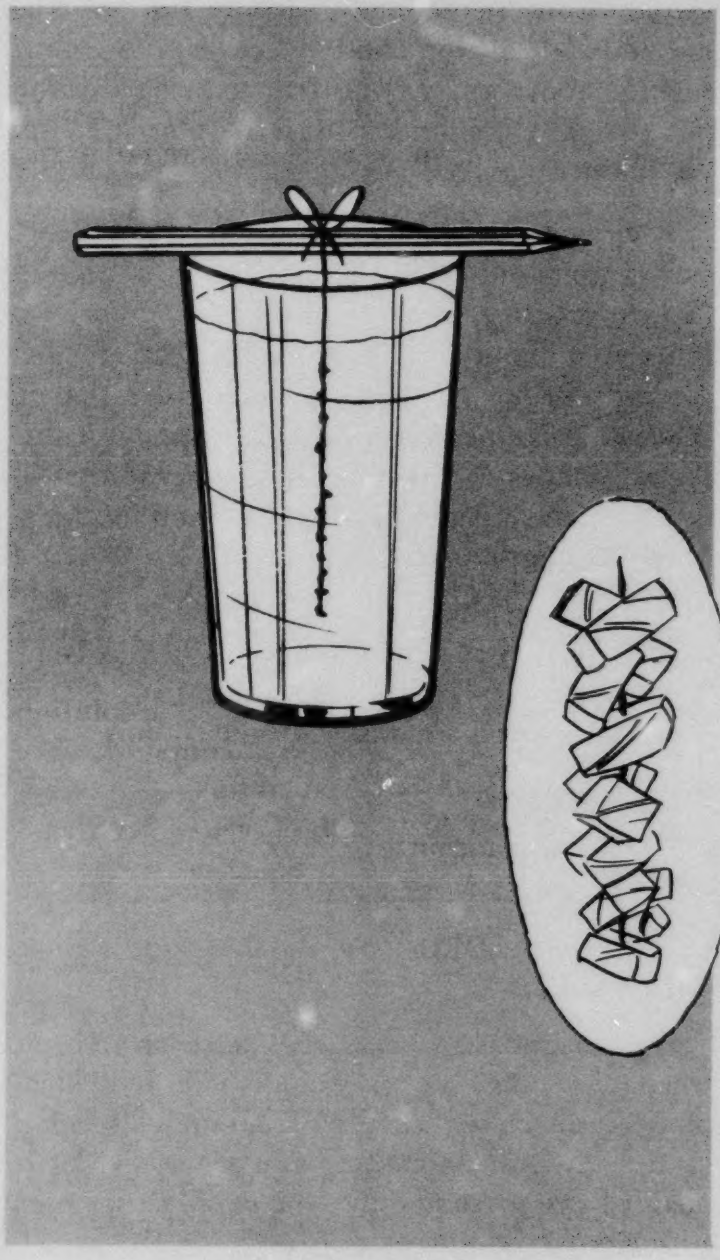
If enough carbon dioxide has formed, it will slowly pour out of the bottle. You won't see it happen because carbon dioxide is colorless. Since it is about 1½ times heavier than air, the gas will begin settling on the candle flame. When that happens, the gas will extinguish the flame. It does this for the simple reason that it deprives the flame of oxygen. And nothing burns without oxygen, as you know.

If you weren't successful in putting out the candle, start with a new supply of baking soda and vinegar. Only this time, act a little faster and skip the pressure test with the thumb.

EXPERIMENT 12: Candy Crystals From a Sugar Solution

THINGS NEEDED: *Sugar. Drinking glass. Cotton thread.*

What happens to materials like sugar and salt when they dissolve in water? The individual pieces change size. They go from grains to molecules . . . from something you can see with the unaided eye to something you couldn't see even with a powerful microscope.



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A molecule of sugar, for example, is the smallest particle of sugar that can exist. If that particle were any smaller, it couldn't be sugar. It would be some material whose molecules are not as big as sugar molecules.

In this chemistry experiment on solutions and crystals, we're going to convert sugar grains to sugar molecules. Then from the molecules we'll let the sugar re-form into large crystals – crystals big enough, clean enough, and good enough to eat. In other words, we're going to make rock candy.

Put a cup of water into a small pot, and bring it to a boil. When it starts to boil, turn off the heat, add about 1½ cups of sugar, and stir. If all the sugar dissolves, add a little more. Keep adding sugar until no more will dissolve. The solution will then be saturated, meaning it contains all the sugar it can hold at that temperature.

After the solution has cooled, pour it into a drinking glass. Next hang a piece of cotton thread all the way into the solution. Support it from a stirring rod or pencil laid across the top of the glass. Then put the glass in a place where it will stay cool and undisturbed for a while.

As the solution cools, it becomes supersaturated. Crystals will start forming on the string. After a few days, the crystals should be fairly large. You can remove the string and enjoy the sweet reward of a successful experiment.

Edison in his chemical laboratory in 1906. This building is now a part of the Edison National Historic Site in New Jersey.

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